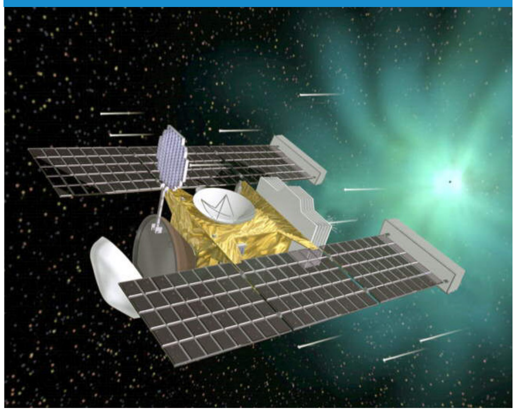
National Aeronautics and Space Administration

*Materials Characterization*

# Stardust Materials Analysis

**NASA Marshall Space Flight Center**



In January 2006, after a nearly 7-year-long voyage through space to and from a rendezvous with Comet Wild 2, the Stardust spacecraft released a sample return capsule that reentered Earth's atmosphere and parachuted to a soft landing in the Utah desert. While the mission's primary science goal was to capture and return cometary and interstellar dust particles, the capsule and science hardware themselves also returned critical information about how materials weathered the harsh space environment. During the mission, the capsule's components (heat shield and back shell, drogue and main parachute, parachute cords, thermal control surfaces, fasteners, lubricants, adhesives, seals, and electronics) were exposed to the combined effects of ultraviolet radiation, charged particle radiation, high vacuum, and extreme temperatures; these conditions cannot be fully simulated on Earth. This is a unique opportunity for materials engineers to analyze hardware returned from space; what they learn about material behavior and property changes during long-term operation and exposure in space will be applied directly to the materials selection and design of future robotic and human missions.

## Task Description

At Johnson Space Center's Stardust curation site, the Principal Investigator will make non-destructive measurements of non-primary science hardware items to assess their durability in the space environment. Of special interest are:

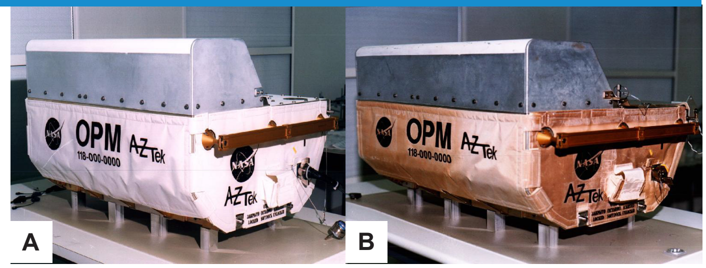
- Ablative materials that protected the blunt body capsule and its payload from the heat of reentry
- Other flight components (avionics box, thermal control surfaces, and deployment/retraction mechanisms).

Data from these non-destructive tests will be compared to existing data for the materials, and a lessons-learned report will be published. Postflight materials data will be archived in the NASA Materials and Processes Technical Information System (MAPTIS) databases. This 10-month study was initiated in December 2005 and will be completed in August 2006.

The Stardust sample return capsule lies in the Utah desert, having traveled 2.88 billion miles before its return to Earth. The gray-blue material covering the left half of the capsule is Phenolic Impregnated Carbon Ablator (PICA), the thermal protection system that shielded the capsule and its contents from the extreme temperatures experienced during travel through Earth's atmosphere. In the artist's concept (above, left), the Stardust spacecraft approaches Comet Wild 2. The sample return capsule is on the left of the spacecraft, with its cosmic dust collector extended.

advanced materials for exploration

# STARDUST MATERIALS ANALYSIS




Multi-layer insulation (MLI) blankets covering the sides of the Optical Properties Monitor darkened unexpectedly [preflight (A); postflight (B)] during its 9-month exposure aboard the Mir space station. Postflight analyses showed that exposure to solar ultraviolet radiation in the vacuum of space degraded the thermal performance of one component of the MLI, causing the color change. Analyses of the Stardust capsule are expected to identify materials changes related to space exposure that will improve the ability of designers to select long-lived materials for future spacecraft.

## Anticipated Results

Non-destructive measurement techniques applied to the Stardust non-primary science hardware will yield data on solar absorptance and infrared emittance. Increases in absorptance may indicate damage related to radiation, while changes in emittance, along with absorptance, affect thermal properties and may indicate degradation of performance beyond desired end-of-life properties. Torque measurements on fasteners may expose galling or reveal other mechanism failures and will be used to evaluate breakaway and running torque values to compare with preflight values. (These measurements may be obtained from the Stardust disassembly team.) Visual and photographic observations of material conditions, particularly of the aeroshell, will show how well the spacecraft's trajectory and its aeroshell heatshield protected the sample return canister.

Postflight analyses may also help determine the source of contamination that affected the spacecraft's navigation camera early in the mission. Black light illumination will reveal particulate and molecular contamination, samples of which will be identified using Fourier Transform Infrared diffuse reflectance measurements. Identification of venting patterns and contaminant deposition on the sample return capsule will assist the Stardust team in determining where this contamination originated. The Principal Investigator will publish a NASA technical paper detailing the spacecraft materials' conditions, measurements performed, evaluation of durability in the space environment, and recommendations for further testing.

## Potential Future Activities

The techniques and data used for this non-destructive postflight assessment of materials properties can be used in the future for the analysis of hardware returned from the Moon and other planets. While each returned mission will have its own lessons and opportunities for future experiments, comparing data from several missions will reveal how the harsh environmental conditions in space erode material, component, and system performance. In addition, researchers will gain insight into new uses for the analysis techniques and develop new protocols that may improve their sensitivity. Marshall Space Flight Center has the facilities, equipment, and materials properties expertise to perform this and future returned flight hardware assessments.

## Capability Readiness Level (CRL)

This Advanced Materials for Exploration (AME) task will analyze subsytem-level flight hardware, confirming the CRL of 7 for these materials and adding safety and reliability data that prove the materials' performance. This knowledge will assist scientists, materials engineers, and designers in developing improved materials or material protection systems for future spacecraft, including those that carry humans far from Earth.

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